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Fig. 1—Panicles of Oats Affected with Loose Smut

The Control of Cereal Smuts by Seed Treatment

By F. D. FROMME

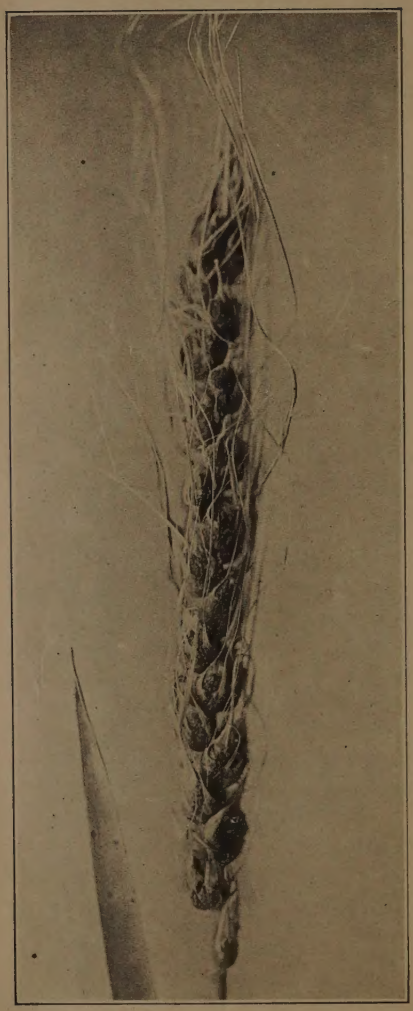

Fig. 2—Covered smut of barley. It differs from loose smut which destroys the head more completely.

THE CONTROL OF CEREAL SMUTS BY SEED TREATMENT[1]

By F. D. Fromme

The practice of seed disinfection for the control of the smut diseases of the cereals, although established in value a number of years ago, has not been adopted as an integral part of seeding practice to the degree that its value justifies. Following years of severe smut losses the practice becomes quite general in some localities in Virginia, but there are comparatively few farmers who treat seed year by year as an insurance against loss.

Failure to treat seed is seldom due to unsatisfactory control; it is more often occasioned by unwillingness to assume the extra labor and trouble or to a degree of uncertainty as to the likelihood of injury to germination. Both objections have been overcome by the introduction of disinfectants which may be used in the dry form. This has been the outstanding recent contribution to the practice of seed treatment and a considerable demand for information on the efficiency and limitations of these materials has arisen. The question of seed disinfection has also been reopened through the recent development of certain organic mercury compounds, for use both in solution and in the dry form, which are claimed not only to be non-toxic to seed when used in proper dosage, but are said to stimulate germination.

There has never been a time in Virginia when there has been such a general demand for high quality seed. It is obvious that freedom from disease is a prime requisite of quality and this is clearly recognized in the production of seed for certification. The demand for better seed and the attempt to satisfy it through better methods of production have stimulated interest in disease control.

The studies reported here were planned to test some of the newer disinfectants as seed treatments for oats, barley, and wheat. Certain other points of interest have developed in the course of the work. There has been no attempt at an exhaustive study of any phase of the problem.

Experiments With the Smuts of Oats

The tests with oats were planned to obtain data on the control of the loose and covered smuts (*Ustilago avenae* and *U. levis*) with copper carbonate

[1]Paper No. 73 from the department of plant pathology.
Edition of 10,000 copies.

and certain other materials which were available at the time.

Seed of V. P. I. No. 1, a black oat selection, were obtained from a crop which showed about 20 per cent. of infected panicles. The treatments were made and seeding was completed on the same day, September 22, 1922. The seeding was done with a drill and a plat 13.2 x 66 feet, one-fiftieth acre in area, was used for each treatment, together with a duplicate plat of one-half that area.

Formaldehyde and Semesan were used in solution and copper carbonate and nickel carbonate were used as dusts. Seed were soaked for two hours in a 1-320 solution of 40 per cent. formaldehyde (0.125%) and for the same period in 0.25 per cent. solution of Semesan. The dusts were used at the rates of 2 ounces and 4 ounces per bushel of grain and were thoroughly mixed with the grain.

One row through the center of each plat was harvested separately on June 6, 1923, and accurate counts of sound and infected panicles were made, as shown in Table 1.

TABLE 1—OCCURRENCE OF OAT SMUTS AS AFFECTED BY SEED TREATMENTS, 1922-1923

Material	Number of panicles	Number infected	Per cent. infected
Check No. 1	2,449	151	6.17
Copper carbonate, 2 oz.	2,160	105	4.86
Copper carbonate, 4 oz.	2,631	115	4.37
Semesan, 2-hr. soak	1,922	66	3.43
Nickel carbonate, 2 oz.	2,440	63	2.58
Nickel carbonate, 4 oz.	2,224	40	1.80
Formaldehyde, 2-hr. soak	2,368	0	0.00
Check No. 2	2,337	162	6.93

The failure to obtain satisfactory control of the oat smuts with copper carbonate is in agreement with findings of other workers who report similar results. Although effective for stinking smut of wheat it does not control the smuts of oats except for hulless varieties. Increased dosage of copper carbonate gave little further reduction in infection. Nickel carbonate proved more effective than copper carbonate and increased dosage produced further reduction in infection. Semesan reduced infection only slightly. The formaldehyde treatment gave complete control. A thorough examination of the entire plat failed to reveal a single infected panicle.

A further test on V. P. I. No. 1 oats was made in the spring of 1924, but the smut infection was so slight that infection percentages were not recorded. Percentages of stand were recorded after all seedlings had emerged in order to judge the effect of treatment. According to claims that have been made, the chlorophenols of mercury stimulate and increase germination, but this was not true under the conditions of the test. The materials used were Chlorophol, Germisan, Uspulun, duPont No. 10, duPont No. 12, Semesan, formaldehyde, Kalimat, and Phythal. All were used in solution according to directions of the

manufacturers. Marked injury resulted from the use of Pythal in 0.75 per cent. concentration for one-half hour, and very severe injury at the same concentration with a one-hour exposure. duPont No. 12, Kalimat, and Chlorophol reduced germination. The other materials gave slightly better germination than the check lots planted dry but did not exceed, and in some instances did not equal, the germination of a check lot that was soaked one hour in water. The formaldehyde treatment was the equal of any.

It appears from the foregoing that formaldehyde is a satisfactory material for the disinfection of oats. Its cheapness and general availability recommend it. There should be no appreciable injury to germination if the grain is seeded as soon as dry enough to run through the drill. Treated grain should not be stored for future seeding. Injury may result if it is stored overnight.

Formaldehyde is commonly used at a dilution of 1 pint in 40 gallons of water or 1 part in 320 parts of water. The grain may be held in the solution for one hour and then spread and seeded when dry enough to permit, or it may be dipped until thoroughly wet, then drained and allowed to stand in the wet sack for two hours before drying and seeding. In another method it is sprinkled with the solution, then piled, and covered for two hours. As a rule, 40 gallons of formaldehyde solution is sufficient for the treatment of 50 bushels of oats. In seeding treated oats allowance should be made for the swelling of the grain. The drill will need to be set to seed about one-fourth more than with dry grain.

Recent studies at the Ohio Experiment Station[1] indicate the development of satisfactory dry preparations of formaldehyde and iodine for oats. These materials are under test in Virginia and if they prove satisfactory will doubtless supplant the wet methods of treatment.

Experiments With the Smuts of Barley

A test of several seed disinfectants in the control of the loose and covered smuts of barley (*Ustilago nuda* and *U. hordei*) was made in 1923.

The seed was of the Tennessee Winter variety obtained from a field which showed about 5 per cent. of heads infected with covered smut and about 1 per cent. of loose smut. The treatments were made on the afternoon of September 27, 1923, and seeding was done on the morning of the 28th. The grain was planted with a hand drill in rows 12 inches apart and 66 feet in length, each treatment occupying a single row. The grain was not washed following treatment and was placed on blotters in the laboratory to air dry.

The barley rows were harvested on June 20, 1924, and counts of infected and sound heads were made. The details of treatment are shown in Table 2, together with the data for covered smut.

[1] J. D. Sayre and R. C. Thomas. Formaldehyde and iodine dusts for the control of oat smut. Ohio Agr. Exp. Sta. Bimonthly Bull. Jan.-Feb. pp. 2-6. 1918.

TABLE 2—OCCURRENCE OF COVERED SMUT OF BARLEY AS AFFECTED BY SEED TREATMENTS, 1923-1924

Material	Concentration	Hours soaked	Total heads	Infected heads	
				No.	Per cent.
Check, dry		0	2,874	199	6.92
Check, wet		1	1,879	73	3.88
duPont No. 10	0.1	1	1,696	92	5.42
duPont No. 10	0.3	1	2,146	97	4.52
duPont No. 10	0.5	1	1,984	69	3.48
duPont No. 12	0.1	1	2,226	51	2.29
duPont No. 12	0.3	1	1,683	26	1.54
duPont No. 12	0.5	1	1,958	37	1.89
Semesan	0.3	1	1,782	35	1.96
Semesan	0.5	1	1,540	24	1.56
Semesan	0.5	2	1,213	7	0.58
Kalimat	0.25	½	1,156	7	0.61
Phythal	0.75	1	2,359	14	0.60
Formaldehyde	0.125	1	1,787	2	0.11
Hot water*		*	2,000	0	0.00

*The hot water treatment consisted of a presoak of 4 hours in water at room temperature followed by 10 minutes in water at 129 degrees F.

The hot water treatment alone, of those tested, gave complete control of covered smut. Formaldehyde proved second to hot water in efficiency and gave a very satisfactory control, the percentage of infected heads being only 0.11. Phythal, Kalimat, and Semesan (2 hours' soak in 0.5 per cent. concentration) reduced the percentage of infected heads below 1 per cent., while the other materials were less effective. The dry check produced 6.92 per cent. infected heads and seed of the same lot soaked for 1 hour in cold water produced 3.88 per cent. of infected heads. Increased concentration of the disinfectant lowered infection as a general rule.

The percentage of loose smut in the check plats was only 0.52 for the dry check and 0.42 for the wet check. In the treated lots the percentage varied, with experimental error, between 0.26 and 1.47 per cent., except for the hot water treatment which gave complete control. None of the chemical treatments produced an apparent measure of control.

The barley seed harvested from the wet check in 1924 was used in further tests on October 3 of that year, but no smut infection developed. The failure to develop infection may have been due to the manner of harvesting and threshing, the infected heads having been segregated before threshing, or it may have resulted from winter killing which was quite severe in barley in that year. Some data on the effect of disinfectants on germination were, however, obtained and these are recorded in Table 3.

The seed was treated on October 3, and 350 seed of each lot were planted in rows in the field on that date. The remaining seed of each treatment lot was stored in the laboratory until October 6, when the germination tests were made. One hundred seed of each lot were placed in moist sand at room temperatures and germination counts were made at daily intervals beginning

October 7 and ending October 10. Counts of seedlings were made in the field planting on October 15.

TABLE 3—PERCENTAGE OF GERMINATION OF TENNESSEE WINTER BARLEY AS AFFECTED BY SEED TREATMENT, 1924

Material	Hours soaked	Percentage germination in laboratory				Percentage germination in field
		10/7	10/8	10/9	10/10	
Germisan*	½	86	100			98
Germisan	1	86	98	99	100	98
Semesan	1	75	100			97
Chlorophol	1	40	100			93
Uspulun	1	35	100			91
Uspulun	2	36	98	98	98	94
Kalimat	½	24	100			99
Formaldehyde	1	12	96	100		98
Phythal	½	10	90	100		98
Check, dry	0	42	99	99	99	99
Cold water	1	27	88	99	99	98
Hot water	*	0	88	88	97	95
Copper carbonate	0	64	100			99
Semesan dust	0	49	100			100
Bayer dust, No. 3	0	36	100			99

*Germisan, Semesan, Uspulun, and Kalimat were used in 0.25 per cent. solution; Chlorophol in 0.3 per cent.; formaldehyde in 0.125, and Phythal in 0.75 per cent. The hot water treatment was used as in the preceding test.

It is apparent that none of the treatments caused injury of any consequence to germination, although a few of them delayed germination. This was true especially of the hot water treatment, and to a slight degree of the formaldehyde and Phythal treatments. As compared with the cold water check a few materials appeared to accelerate germination. This was especially true of Germisan, Semesan, and Chlorophol. Of the dry treatments, copper carbonate alone appeared to accelerate germination as compared with the dry check.

Of the chemical disinfectants employed in the treatment of barley seed, formaldehyde appears to be most satisfactory. It controls covered smut satisfactorily and in some instances reduces loose smut infection. The hot water treatment is to be preferred where loose smut is an important factor, since it provides effective control of both loose and covered smut, but its use is not justified in preference to formaldehyde under average conditions, because of the added inconvenience and cost.

Experiments With Seed Treatment of Wheat

A preliminary test of two materials, copper carbonate and Semesan, was made in 1922 with wheat of a beardless variety which contained a number of unbroken galls of stinking smut or bunt (*Tilletia levis*) and was quite dark with spores. The seed was treated without cleaning or removal of the smut galls. Copper carbonate was used at the rate of 2 ounces per bushel of grain

and Semesan was used in 0.5 per cent. solution, the seed being soaked for two hours. Each lot was seeded with a hand drill in a single row 66 feet in length.

Fig. 3—Heads of wheat affected with bunt. The glumes have an unusual flare, the grains having been replaced by smut galls.

The wheat was harvested June 21, 1923, and counts of heads were made as shown in Table 4. The control obtained with both Semesan and copper carbonate was quite satisfactory when the severity of infection is considered.

TABLE 4—THE EFFECT OF SEED TREATMENTS ON THE OCCURRENCE OF BUNT IN WHEAT 1922-1923

Material	Total heads	Infected heads	
		No.	per cent.
Check	257	83	32.29
Copper carbonate	608	5	0.82
Semesan	375	2	0.53

An identical test, with the same materials and at the same time, was made with wheat containing nematode galls (*Tylenchus tritici*) to the extent of 7 per cent. Neither material showed any reduction in the resulting infection, and as a matter of fact both appreciably exceeded the check plat in percent-

ages of infected heads. There were 50.7 per cent. of infected heads in the copper carbonate plat, 39.5 per cent. in the Semesan plat, and 11.4 per cent. in the check. The stand of the check plat was greatly reduced, the number of heads being only 26 per cent. of that of the copper carbonate plat and 31 per cent. of that of the Semesan plat. It is perhaps significant that this reduction in stand agrees closely with the reduction in infection. The percentage of infected heads in the check was 22 per cent. of that of the copper carbonate plat and 29 per cent. of that of the Semesan plat. It is apparent from these comparisons that there was a higher death rate or greater failure to head in the plat seeded with untreated seed than in those seeded with treated seed, and this probably explains the difference in percntages of infected heads at harvest. A plausible interpretation, therefore, is that the disinfectants reduced the intensity of infection which permitted a higher percentage of infected plants to survive and produce heads.

The effect of certain disinfectants on germination of wheat and on the control of loose smut (*Ustilago tritici*) was determined in 1923 with wheat of the Fulcaster variety. The seed was obtained from a field which showed 8

Fig. 4—A crop of wheat severely affected with loose smut

per cent. of infected heads, but unfortunately the check plat at harvest showed only 1.78 per cent. The materials employed were Semesan, duPont No. 10, duPont No. 12, Kalimat, Phythal, and hot water. None reduced infection except hot water, which gave complete control. There was no marked reduction in stand or increase in stand from any treatment.

A further test of the effect of certain disinfectants on the germination of wheat was made October 3, 1924. A portion of each lot was seeded in the field on that date and another portion was used in laboratory germination tests. The field test included 350 seed and the laboratory test 100 seed. Germination in the laboratory was recorded daily for five days. The field readings were made October 15, twelve days after seeding. Data are recorded in Table 5.

TABLE 5—PERCENTAGES OF GERMINATION OF WHEAT AS AFFECTED BY DISINFECTANTS AND OTHER TREATMENTS, OCTOBER, 1924

Material	Concentration	Hours soaked	Laboratory					Field
			10/7	10/8	10/9	10/10	10/11	10/15
Cold water		1	73	84	89			81
Germisan	0.25	½	29	86	92	95		88
Germisan	0.25	1	5	58	88	95	97	79
Kalimat	0.25	½	25	83	85	88	92	71
Semesan	0.25	1	8	86	90	95	96	85
Uspulun	0.25	1	6	80	89	95		84
Formaldehyde	0.125	1	8	85	92	97		67
Phythal	0.75	½	7	86	86	95		85
Hot water		*	7	85	95			65
Chlorophol	0.3	1	0	69	83	89	94	86
Check, dry		0	25	92	96	97		81
Bayer Dust No. 3		0	48	93	96	97		89
Semesan Dust		0	9	92	96	97		91
Copper carbonate		0	0	50	85	95	98	84

*A 10-minute exposure in water at 129 degrees F. following a 4-hour presoak in cold water.

The following points are indicated from the laboratory tests. All of the wet treatments delayed germination as compared with the cold water soak of one hour, but the initial delay was overcome in all cases and the final percentages of germination recorded for all wet treatments exceeded that of the check. None of the dry treatments equalled the wet check in rapidity of germination, but all exceeded it in final percentage of germination. As compared with the dry check, Bayer dust alone of the dry treatments showed early acceleration of germination, while copper carbonate showed appreciable delay.

The stand of the cold water check in the field was exceeded by Germisan, Chlorophol, Semesan, Phythal, and Uspulun. Kalimat, formaldehyde, and hot water showed a reduction of stand. The stand of the dry check, which was identical with that of the wet check, was exceeded by all of the dry disinfectants.

Wheat of four lots, all severely affected with bunt, was used in a comparison of the efficiency of some seed disinfectants in 1925. Lots A, B, and C, were obtained from Woodstock, and Lot D from Maurertown. All treatments were

made on October 9 and seeding was completed the same day. Each treatment lot contained 100 grams of seed and was sown with a hand drill in a single row 66 feet long. The rows were spaced 10 inches apart. Although the seeding was done as uniformly as possible, there were times when the drill did not work well and the stand was not as uniform throughout the length of row as would be desired for data on yield. The numbers of heads in the different lots, as shown in Table 6, are not, therefore, as accurate an index of the effect of the treatments on germination and yield as might be desired. The check lots cannot be compared for number of heads with the treated lots, because a slightly greater quantity of seed was used in them.

The following materials were used in solution, Semesan, Uspulun, Germisan, Super-Kalimat, and formaldehyde. Semesan, Uspulun, and Germisan were used in concentrations of 0.25 per cent. and the period of soaking was one hour. Super-Kalimat was used at 0.25 per cent. concentration for 15 minutes. Formaldehyde (40%) was diluted 1 part in 320 parts of water and the period of soak was 1 hour. A wet check was also employed, the seed being soaked for 1 hour in tap water at room temperature. The seed from all wet treatments was placed without washing on blotters to dry immediately following the period of immersion. None of the seed lots had been thoroughly cleaned. Such unbroken smut galls as remained after treatment were removed by hand.

The materials used in dry or dust treatments were: copper carbonate, Bayer dust, Semesan dust, Abavit, Abavit B, No. 1762-B.[1] A dry check was also employed. The smut galls were not removed from any of these lots. An excess of these materials was added to the seed and was thoroughly mixed with it by shaking. A slight excess of the materials remained in the lots and ran through the drill, which was cleaned between seedings to prevent the mixing of materials.

The varieties of wheat used in the tests were unknown, but all were bearded, winter wheats of the Fulcaster type.

The wheat rows were harvested at maturity in June, 1926, and a separation of sound and infected heads was made of the harvested lots, the entire lot of the 66-foot row being counted in each case. The number of heads and the number and percentages of infected heads are shown in Table 6.

As will be noted, the severity of infection in the check lots was ample to provide a thorough test of the materials. The percentages of infected heads ranged from 48.2 to 76.6 per cent. in the wet checks and from 57.1 to 83.9 per cent. in the dry checks.

Complete elimination of bunt was obtained with Super-Kalimat in one lot, with formaldehyde in one lot, with Abavit in two lots, with 1762-B in two lots,

[1]The sources of the disinfectants is indicated in the following: Semesan and Semesan dust, the E. I. duPont de Nemours & Co.; Uspulun and Bayer dust, the Bayer Co.; copper carbonate, the California Spray Chemical Co.; Abavit, Abavit B, and 1762-B, Chemische Fabrik Ludwig Meyer; Germisan, Saccharin-Farbik, Aktiengesellschaft; Super-Kalimat, the Chicago Process Co.

TABLE 6—RESULTS OBTAINED WITH SEED DISINFECTANTS IN CONTROL OF BUNT OF WHEAT
1925-1926

Material used	Lot A			Lot B			Lot C			Lot D		
	Total heads	Infected		Total heads	Infected		Total heads	Infected		Total heads	Infected	
		No.	%		No.	%		No.	%		No.	%
Check (wet)	2,721	2,085	76.6	2,516	1,124	43.0	2,226	1,079	48.5	2,741	1,321	48.2
Super-Kalimat	2,198	2	0.1	2,019	1	0.1	2,119	0	0.0	1,696	2	0.1
Formaldehyde	1,814	1	0.1	1,571	0	0.0	1,602	2	0.1	1,539	7	0.5
Uspulun	1,688	5	0.3	1,447	6	0.4	1,639	2	0.1	1,936	5	0.3
Semesan	2,442	24	1.0	1,912	5	0.3	1,862	11	0.6	2,431	18	0.7
Germisan	2,107	11	0.5	2,168	69	3.2	2,175	101	4.6	2,160	44	2.0
Check (dry)	2,896	2,430	83.9	2,292	1,308	57.1	2,419	1,516	62.7	2,386	1,456	61.0
1762-B	855	0	0.0	1,410	0	0.0	1,956	1	0.1	1,517	1	0.1
Abavit	1,703	8	0.5	1,673	0	0.0	1,677	0	0.0	1,818	1	0.1
Abavit B	1,659	9	0.5	1,817	4	0.2	1,600	0	0.0	1,507	0	0.0
Copper carbonate	1,724	8	0.5	1,736	6	0.3	1,608	0	0.0	1,997	4	0.2
Bayer Dust	1,677	21	1.2	1,590	2	0.1	1,892	20	1.1	2,081	37	1.8
Semesan dust	1,966	10	0.5	816	10	1.2	1,672	40	2.4	1,470	15	1.0

with Abavit B in two lots, and with copper carbonate in one lot. Almost complete elimination was obtained in certain other lots.

The data for the four lots of seed are combined and averaged in Table 7. The wet treatments are listed in the order of their efficiency under the wet check and the dry treatments in similar order under the dry check.

TABLE 7—SUMMARY OF DATA FROM TABLE 6, AVERAGED FOR ALL LOTS

Material	Total heads	Infected	
		No.	Per cent.
Check (wet)	10,204	5,609	55.0
Super-Kalimat	8,032	5	0.1
Formaldehyde	6,526	10	0.2
Uspulun	6,710	18	0.3
Semesan	7,647	58	0.8
Germisan	8,610	225	2.6
Check (dry)	9,993	6,710	67.1
1762-B	5,738	2	0.1
Abavit	6,871	9	0.1
Abavit B	6,583	13	0.2
Copper carbonate	7,065	18	0.3
Bayer dust	7,240	80	1.1
Semesan dust	5,924	75	1.3

The dry treatments, as will be noted, are in general fully as effective, if not more so, than the wet treatments. When it is considered that the smut galls were not removed from the dry lots, as they were in the wet lots, it appears that the dry treatments were subjected to the more severe test. The percentage of infection is consistently higher in the dry checks than in the wet checks, the average for the former being 67.1 per cent. as compared with 55 per cent. for the latter. Of the materials used as dry disinfectants 1762-B, Abavit, Abavit B, and copper carbonate were most effective, while Super-Kalimat, formaldehyde, and Uspulun were the most effective wet disinfectants. It seems probable, however, that all of the materials employed would give

satisfactory results under average conditions of farm practice, since no farmer would be likely to use grain as seed so heavily smutted as that used in our tests.

An additional series of tests which were planned to determine the value of thorough removal of smut galls as an aid in control of bunt accompanied the foregoing series of treatments. Three brands of copper carbonate were compared, together with other dust materials. The "Ortho" copper carbonate was obtained from the California Spray Chemical Company. Two samples of copper carbnoate were supplied by J. R. Lintner, county agent, of Leesburg. The "Copper Carb" was manufactured by the Corona Chemical Company and the other sample, which we have designated ("blue") was purchased from the Growers and Producers' Exchange, of Roanoke.

The wheat seed was obtained from a mill at Woodstock and contained 18 per cent. of unbroken smut galls. Treating and seeding were completed on October 13, 1925, each lot being seeded in a single row 66 feet in length.

Prior to the treatment, the bunt galls were removed by hand from a portion of the seed which is designated "cleaned" in the discussion that follows. The portion from which the galls were not removed is designated "uncleaned."

The quantity of dusts used in this series was only that which the seed would retain. After treatment the seed was placed in a sieve and shaken to remove the excess material.

The lot designated "skimmed and washed" was first placed in water and the floating galls and trash were skimmed off. It was then placed in a sieve and washed thoroughly in a stream of water for an hour. Microscopic examination at the end of the period still showed an abundance of smut spores on the brush ends of the grains, but to the eye the wheat appeared bright and clean.

The wheat heads were harvested and counted in the same manner as the preceding series. Data obtained are shown in Table 8.

TABLE 8—NUMBER AND PERCENTAGES OF BUNT-INFECTED HEADS RESULTING FROM VARIOUS SEED TREATMENTS, 1925-1926

Condition of seed	Material used	Total heads	Infected heads	
			No.	%
Cleaned	Copper carbonate (blue)	863	1	0.1
	Copper carbonate, "Ortho"	1,613	2	0.1
	"Copper Carb"	2,000	4	0.2
	Bayer dust	1,523	34	2.2
	Semesan dust	1,454	40	2.8
	Check	2,040	800	39.2
Uncleaned	Copper carbonate (blue)	1,632	6	0.4
	Copper carbonate, "Ortho"	1,680	8	0.5
	"Copper Carb"	2,051	124	6.0
	Bayer dust	1,877	120	6.4
	Semesan dust	1,382	81	5.9
	Check	2,270	1,233	54.3
Skimmed and washed for one hour		1,602	13	0.8

The effect of cleaning is apparent when the same materials are compared in the cleaned and uncleaned series. Without exception the uncleaned lots show a higher percentage of smutted heads although the increases are not so great as might have been expected. The uncleaned check showed 54.3 per cent. of smutted heads, while the cleaned check showed 39.2 per cent.

Two brands of copper carbonate gave satisfactory control of bunt, even in the uncleaned lot, while all three were efficient with the cleaned seed. The other dust materials did not equal copper carbonate in efficiency by a considerable margin.

Perhaps the most interesting feature of this series of tests is the results obtained with the lot of seed that was skimmed and washed in running water. As stated previously, every grain examined still retained a number of bunt spores after washing, but only 0.8 per cent. of infected heads developed. Further data on the effects of washing and of seed disinfectants were obtained in the following year.

The seed used in the tests of 1926 were quite black with smut spores and contained a number of smut galls, which were removed by skimming where wet treatments were employed and by hand separation for dry treatments. Treatment and seeding were completed on October 2, 1926. All of the disinfectants employed were used in the dry form. The dusts were applied in excess and the excess was later removed by screening. Included with the recognized disinfectants were certain materials, dusting sulfur, dry-mix and copper-lime dust, which were thought to have possible value and certain others, hydrated lime, gypsum, and talc, which were considered to be of very doubtful value. Claims of satisfactory control of bunt with hydrated lime have been brought to our attention, hence its inclusion in the test. The wet check was soaked for one hour in cold water, while the washed lot was placed under the tap and was washed continuously in a stream of water. Samples of 30 grams were removed at intervals of 15, 30, 45, 60, and 120 minutes. All lots were seeded by hand in 10-foot rows. Bunt infection data were obtained at harvest in July, 1926, and are recorded in Table 9.

As will be apparent, the gypsum, talc, and hydrated lime applications gave no measure of control. Copper-lime dust and dry-mix reduced infection appreciably, while dusting sulfur gave complete control. duPont 50 and 53 were not as effective as the other commercial disinfectants, all of which gave complete control. The test was not especially severe. The dry check developed 5.84 per cent. infected heads and the wet check 6.48 per cent.

Washing in running water again reduced infection materially. A wash of but 15 minutes reduced the percentage of infected heads to 0.9, and additional washing resulted in further reduction.

One may conclude from the consistent results of the two seasons that marked reduction in bunt infection results from thorough washing of the grain. That this is to be attributed to the mechanical removal of spores by

TABLE 9—EFFECT OF VARIOUS MATERIALS APPLIED AS DUSTS, AND OF WASHING FOR STATED PERIODS ON THE OCCURRENCE OF BUNT IN WHEAT, 1926-1927

Treatment	Number of heads	Number infected	Percentage infected
Check, soaked one hour	386	25	6.48
Check, dry	428	25	5.84
Gypsum	339	40	11.80
Talc	312	18	5.77
Hydrated lime	347	17	4.90
duPont 50	498	2	0.40
duPont 53	376	1	0.27
Copper-lime dust*	374	1	0.27
Dry-mix	403	1	0.25
Dusting sulfur	323	0	none
Copper carbonate	477	0	none
Abavit	479	0	none
Abavit B	371	0	none
1762-B	472	0	none
Bayer dust	453	0	none
Semesan Bel	501	0	none
Washed 15 minutes	442	4	0.90
Washed 30 minutes	423	2	0.47
Washed 45 minutes	385	2	0.52
Washed 60 minutes	382	0	none
Washed 120 minutes	354	1	0.28

*The copper-lime dust contained 20 parts anhydrous copper sulfate and 80 parts hydrated lime. The dry-mix contained 8 pounds dusting sulfur (200 mesh), 8 pounds hydrated lime, and ½ pound calcium caseinate spreader.

the stream of water seems evident. The action of water alone is not involved, since the lot which was soaked 60 minutes in still water showed no reduction in infection. According to the studies of Heald[1], there must be certain minimum number of bunt spores on the wheat grain to produce the maximum degree of infection. He found it necessary to apply at least ½ gram of spores to 100 grams of grain to produce the maximum percentage of infected heads. It was evident from both macroscopic and microscopic examination that the spore load of the grain employed in our tests was greatly reduced by washing, apparently much below the minimum requirements for infection such as obtained in the check lots.

The washing of grain as an aid to the control of bunt is not held to be a practical procedure or a substitute for the more simple and efficient dust disinfectants. It is apparent that several of these may be employed with assurance of satisfactory results. Dust disinfectants are easily and quickly applied, they are relatively inexpensive, and they obviate the possibility of recontamination following treatment such as may result when grain treated with solutions is returned to dirty sacks or bins, or is seeded with contaminated drills. Grain treated with dusts may be stored for considerable periods prior to seeding and the presence of the dust may serve the additional purpose of protection against pests that attack stored grain. Such grain should not be used for milling purposes or as food for animals.

Occasional complaints of damage to drills used in the seeding of grain treated with copper carbonate have been investigated by C. T. Gregory and

[1]Heald, F. D. The relation of spore load to the per cent. of stinking smut appearing in the crop. Phytopathology 11:270-278, 1922.

I. D. Mayer[1]. Their experiments indicate that such damage may result if treated wheat is left in the drill over night or longer during wet weather. The drill should be cleaned at the end of the day's seeding. If this has not been done the feed wheels should be tapped and the drill worked back and forth to loosen any cementing action that has taken place. The sudden application of power may result in the breaking of the drill.

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[1]Observations on damage to drills by copper carbonate treated wheat. Proceedings Indiana Academy of Science, 34:265-267. 1925 (1926).